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**Observatorio San Calixto**

**CASILLA 203**

**LA PAZ - BOLIVIA**

**FINAL SCIENTIFIC REPORT**

**TO : AIR FORCE OFFICE OF SCIENTIFIC RESEARCH**  
**FROM: OBSERVATORIO SAN CALIXTO.-La Paz, BOLIVIA**  
**SUBJECT: GRANT No. AF-AFOSR-1177-67 Modification No AFOSR-67-1177C**  
**TITLE: INFRASONIC RESEARCH-PEÑAS ACOUSTIC ARRAY**  
**INCEPTION: October 16, 1966**  
**TERMINATION: September 15, 1968**  
**AMOUNT: \$ 26,980.00**  
**ARPA ORDER 846-67**  
**PRINCIPAL INVESTIGATOR: Dr. Luis M. Fernández**

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**PURPOSE OF THE RESEARCH**

The infrasonic acoustic array of Peñas was installed with the purpose of detecting and investigating the micro-barographic disturbances of the atmosphere produced by natural or artificial sources.

Since the Peñas installation was the first one to be operated in the Southern Hemisphere, an special purpose of the array was to investigate in detail the numerous sources of infrasound located in this hemisphere.

Another purpose of the research was to investigate the influence of the extraordinary conditions of the high Bolivian Altiplano on the reception of infrasonic signals.

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## RESULTS OF THE RESEARCH

### a) Instrumentation:

The original system of microbarographs, amplifiers, recording system, etc. has proved to be reliable and operative in the severe conditions of the Bolivian Altiplano. The installation has been improved in a few ways:

In order to provide sufficient protection for lightning so frequent in the Altiplano, near the Cordillera Real of the Andes, thyrector protectors have been installed. This protection has been sufficient and reliable.

A new time programmer has been added to the system in such a way that the time code coincides with the time code used by the Huancayo array of Peru facilitating the join analysis of the data magnetic tapes.

The calibration of the four microbarographs has been standarized with the same displacements amplitudes of the records representing the same changes of atmospheric pressure.

To facilitate the preliminary detection of infrasonic signals, an electronic energy autocorrelator has been built and connected in line with the recording system of the station. Specifications of the instrument and its performance are indicated in publication No. 4.

### b) Detection of infrasonic signals.

The infrasonic array of Peñas has been proved to be extremely effective for the reception of signals arriving from

the South Pacific area. This condition is the result of several factors affecting the site of Peñas. The high elevation of the station, 14.000 feet above the sea level and the low density of the air affects in a favorable way the signal-to-noise ratio. The general direction of the winds in the Pacific area favors the reception of any event taking place in the Pacific Ocean. The meteorological conditions of the Bolivian Altiplano are such that during the night the infrasonic noise is very low and about 20 times below the level of noise during the day. This condition makes the hours of the night specially suitable for the reception of intrasonic signals. A last condition which has influence on the noise level of the records is the little influence of the jet stream at the latitude of the station.

These series of circumstances has been decisive for the excellent reception of infrasonic signals in Peñas as indicated in publications 1, 2 and 3.

#### Analysis of Infrasonic signals.

The most important parameters of infrasonic waves are the intensity of the pressure difference, the direction of the source and the horizontal velocity of propagation across the array. All these parameters may be accurately estimated using the multicorrelation searcher program indicated in publication No. 3.

The spectral analysis of the signal as a function of

time can be applied to investigate the coefficient of coherence, the signal to noise ratio and the attenuation of infrasonic waves with distance as a function of the periodicity of the wave. This has been done for selected acoustic signals and noise as generated by different sources like volcanic explosions, earthquakes, thermonuclear explosions and wind, as indicated in references No. 1, 2 and 3. Digital programs developed at the Observatory may be applied to the analysis of new signals.

The group and phase velocity of the infrasonic signals has been also evaluated in several cases. The presence of different modes at the same time and the rather special character of dispersion presented by the infrasonic signals are the main reasons for the scattering of observed data. Conventional methods to determine the group and phase velocity based on direct readings of the peaks and periods or in Fourier analysis look not to be sufficient. More powerful methods based on multiple filtering are expected to give more accurate dispersion curves.

#### PRESENTATION OF RESULTS

##### Publications:

1) "Extracción de señales desde un fondo de ruido" by Eliseo J. Guanica. Thesis presented to the Engineering School of San Andrés University, La Paz, Bolivia, 1967.

2) "Propagation of Infrasonic Acoustic Waves in the Souther Hemisphere and their correlation with long period seismic"

noise" Technical Report by Luis M. Fernández and Eliseo Guanica San Calixto Observatorio. La Paz, Bolivia, 1967.

3) "Infrasonic Acoustic Waves generated by the thermo-nuclear Explosion of August 24, 1968." Scientific Report by Luis M. Fernández, José Flores and Jorge Cosulich. San Calixto Observatorio. La Paz, Bolivia, 1968.

4) "Infrasonic Energy Autocorrelator" Technical Report by José Flores, San Calixto Observatorio. La Paz, Bolivia, 1968.

Communications to Scientific Meetings

- 1) Vela Uniform Research Review. AFOSR/AFCL. "The Peñas array" Arlington, Virginia, 4-5 of April, 1968.
- 2) American Geophysical Union. Fall Meeting of 1968. Infrasonic Waves generated by the Volcanic Explosion of the Galapagos Islands. In collaboration with Harry Matheson and Jean Lanat. San Francisco 2-5 December 1968.
- 3) Program Review. AFOSR/ARPA. Isotopes Co. Westwood N.J. "The infrasonic Array of Peñas, Bolivia." 12-13 December, 1968.

The principal Investigator has visited several centers of analysis and research and the Peñas station has been visited by numerous scientists. All these meetings have offered a continuous exchange of ideas and data with numerous organizations and research centers dealing with infrasonic waves.

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13. ABSTRACT

The infrasonic acoustic array of Penas was installed for the purpose of detecting and investigating the microbarographic disturbances of the atmosphere produced by natural or artificial sources. Since the Penas installation was the first one to be operated in the Southern Hemisphere a special purpose of the array was to investigate in detail the numerous sources of infrasound located in this hemisphere. Another purpose of the research was to investigate the influence of the extraordinary conditions of the high Bolivian Altiplano on the reception of infrasonic signals.

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Infrasound sources  
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